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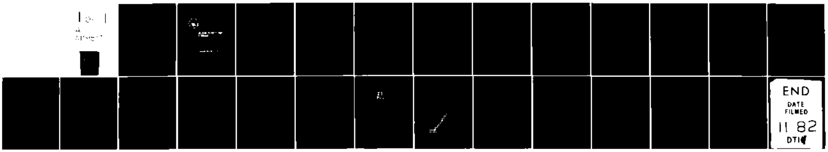

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Basic design guidance for helium storage, repurification, and distribution facilities, Category Code 142, is presented for use by experienced architects and engineers. The contents include helium characteristics, storage data, handling techniques, receiving facilities, working pressures, pipe sizing and strengths, valving, and cleaning and condensing techniques.

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NAVFAC DM-24.2
JUNE 1980

HELIUM PLANTS AND STORAGE

DESIGN MANUAL 24.2

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ABSTRACT

Basic design guidance for helium storage, repurification, and distribution facilities, Category Code 142, is presented for use by experienced architects and engineers. The contents include helium characteristics, storage data, handling techniques, receiving facilities, working pressures, pipe sizing and strengths, valving, and cleaning and condensing techniques.

FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command, other Government agencies, and the private sector. This manual uses, to the maximum extent feasible, national professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters (Code 04). As the design manuals are revised, they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with SECNAVINST 5600.16.

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LAND OPERATIONAL FACILITIES DESIGN MANUALS

DM No.	Chapter Superseded in Basic DM-24	Title
24.1	1 & 3	Buildings and Other Structures
24.2	2	Helium Plants and Storage
24.3	4	Oxacetylene, Nitrogen and Breathing Oxygen Facilities

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HELIUM PLANTS AND STORAGE

FIGURES

TABLES

HELIUM PLANTS AND STORAGE

Section 1. DESIGN CRITERIA

1. SCOPE. Data and criteria in this chapter shall govern the design of helium storage, repurification, and distribution facilities.

2. CANCELLATION. This manual, NAVFAC DM-24.2, cancels and supersedes Chapter 2, of NAVFAC DM-24, dated June 1975.

3. RELATED CRITERIA. Other criteria related to helium appear elsewhere in the DM series. See these sources:

Subject	Source
Compressed air	NAVFAC DM-3 Series
Fire protection engineering	NAVFAC DM-8
Plumbing, heating, and ventilating	NAVFAC DM-3 Series

4. INFORMATION REQUIRED FOR DESIGN. Obtain the following data on the project:
   (1) Schematic flow diagram for desired operating features.
   (2) Plot plan of project to supply location of buildings, railroads, thoroughfares, interferences, and terrain.
   (3) Duration of requirements for working time and standby time.
   (4) Volumetric, pressure, and temperature requirements.
   (5) Local material and labor construction costs.
   (6) Soil conditions.
   (7) Weather and climatic conditions.

5. FACTS ON HELIUM. Federal agencies use helium in helium-shielded arc welding, supersonic wind tunnels, and atomic reactors, and for nuclear, cryogenic and guided missile work. Industrial, medical, scientific, and research organizations use some helium on essential projects.

a. Production. The Department of the Interior, Bureau of Mines, is the only supplier of helium. About 60,000,000 cubic feet at 70°F and 14.7 pounds per square inch absolute (psia) of Grade A helium is produced annually from natural gas in its five plants. The Bureau of Mines sells helium to other Federal agencies (and to private industry at a slightly higher cost) in accordance with Title 30, Code of Federal Regulations. It is anticipated that the Bureau of Mines can meet helium needs, before depletion, to the year 2000.

b. Shipping Facilities. Helium is shipped from the production plants in railroad tank cars containing thirty 18-inch diameter by 33-foot long, seamless steel cylinders (meeting Interstate Commerce Commission (ICC) Specification 107A requirements), with a total volume of about 1225 cubic feet. At 3600 pounds per square inch gage (psig), this volume represents 300,000 cubic feet of helium gas at 70°F at 14.7 psia; at 2400 psig, it represents 200,000 cubic feet.

c. Characteristics.

(1) Grade A Helium. This grade, as received in tank cars, is 99.995 percent pure. It is a mono-atomic, chemically inert gas, colorless, odorless, tasteless, and nonflammable. Other characteristics are:

Characteristics	Value
Liquefaction temperature	- 452°F
Specific volume	96.71 cu ft/lb
Specific weight at 70°F and 14.7 psia	0.01035 lb/cu ft
Specific gravity (air)	0.1380
Specific heat:	
At constant pressure	1.25 Btu/lb/°F
At constant volume	0.754

Helium diffuses more rapidly, flows through a hole faster, conducts heat better, and transmits sound faster than any other gas except hydrogen.

(2) Grade D Helium. This gas has suffered contamination with air and other impurities. It can be as much as 98 percent pure and as low as 80 percent pure.

Section 2. PLANT AND STORAGE DESIGNS

1. RECEIVING FACILITIES. Provide rail spur, truck trailer facilities, and compressors as appropriate.

a. Rail Spur. Where the storage is accessible to a railroad, provide a rail spur connected by piping to high pressure storage tanks, booster compressor station, truck trailer station, and transfer shop. The length of spur shall be sufficient to hold a train of tank cars having a capacity equal to the total capacity of the high pressure storage tanks.

b. Truck Trailer. Where deliveries are made by truck trailer, provide a truck unloading point connected by piping to the high pressure storage tanks, the booster compressor station, and the transfer shop. Provide another compressor station at the nearest railroad connection for transferring helium from railroad tank car to truck trailer.

c. Compressor Station. Generally, the initial filling of the high pressure storage tanks from railroad tank cars is by pressure equalization.

(1) Booster Compressors. Where a repurification plant is not included, provide two booster compressors (one a spare) for emptying either tank car or truck trailer cylinders, and for boosting the pressure in the high pressure storage tanks to the extent required.

(2) Compressor Design. Compressors shall be of the diaphragm nonlubricated type of 2.3 cubic feet per minute piston displacement or equal, with both suction and discharge sides good for 3,500 pounds psig. If the project must also be designed for hydrogen storage in the future, the compressors must be suitable for handling this gas.

2. STORAGE FACILITIES. Special requirements for helium storage are as follows:

a. High Pressure Storage.

(1) Storage Capacity. This capacity for high pressure Grade A helium shall be slightly in excess (depending on previous experience) of that necessary for the project, and divided into several tanks. If possible, a spare tank should be provided for standby.

(a) For supersonic wind tunnel, the storage requirements shall be for one blowdown cycle.

(b) In a once-through cooling system for a rocket engine, the requirement between initial and final pressures shall be one t[illegible]t run, with replenishment available at the receiving station for the nex[illegible]st.

(2) Volumetric Capacity and Cylinder Pressure. High [illegible]ssure helium is stored in cylinders. Where a definite high operating pres[illegible] is not a requirement, both number of cylinders and gas pressures for a [illegible]ain storage capacity shall be balanced against costs to determine the opt[illegible]rrangement. For example, it requires twice as many cylinders to hold the [illegible] quantity of helium at 1200 psig as at 2400 psig.

(3) Cylinder Design. Cylinders shall be made from suitable seamless pipe with either elliptical or swaged ends. Interior surfaces shall be cleaned to bare metal.

(a) Helium use only. Where no flammable gas is to be stored in the cylinders in the future, the cylinders shall be designed in accordance with ASME Section VIII Unfired Pressure Vessel Code (see References) for the required pressure and test pressure, and shall be so certified. They should be similar to Figure 1.

(i) Cylinders shall be stacked horizontally outdoors in banks, cradled near each end by concrete walls, and buried under at least 2 feet of earth as protection against the effect of sun and frost on the internal gas pressures.

(ii) The piped ends shall face a common manifold and be housed in a concrete vault. The cylinders should be pitched slightly toward the piped end so they can be drained.

(b) Future flammable gas use. Where flammable gas such as hydrogen is to be stored in the cylinders in the future, the cylinders shall be designed and installed in accordance with Paragraph 884 of Section 8 of ANSI B31 Code for Pressure Piping (see References).

b. Low Pressure Storage of Grade A Helium. Provide a reserve holder for capturing the contents of Grade A cylinders and piping when they are being emptied. Such a gas holder with water seals, similar to that formerly used at the Lakehurst, N.J., and Weeksville, N.C., Naval Air Station, is illustrated in Figure 2. The holder capacity shall be sufficient to hold the gas in one tank of high pressure storage cylinders.

c. Low Pressure Storage of Grade D Helium. Provide a reserve holder for capturing used helium gas where it can be repurified and used again. At the supersonic wind tunnel installation for the Ames Research Center, illustrated in Figure 3, the used gas mixture of helium and air is stored in closed vacuum spheres (2 to 14.7 psia).

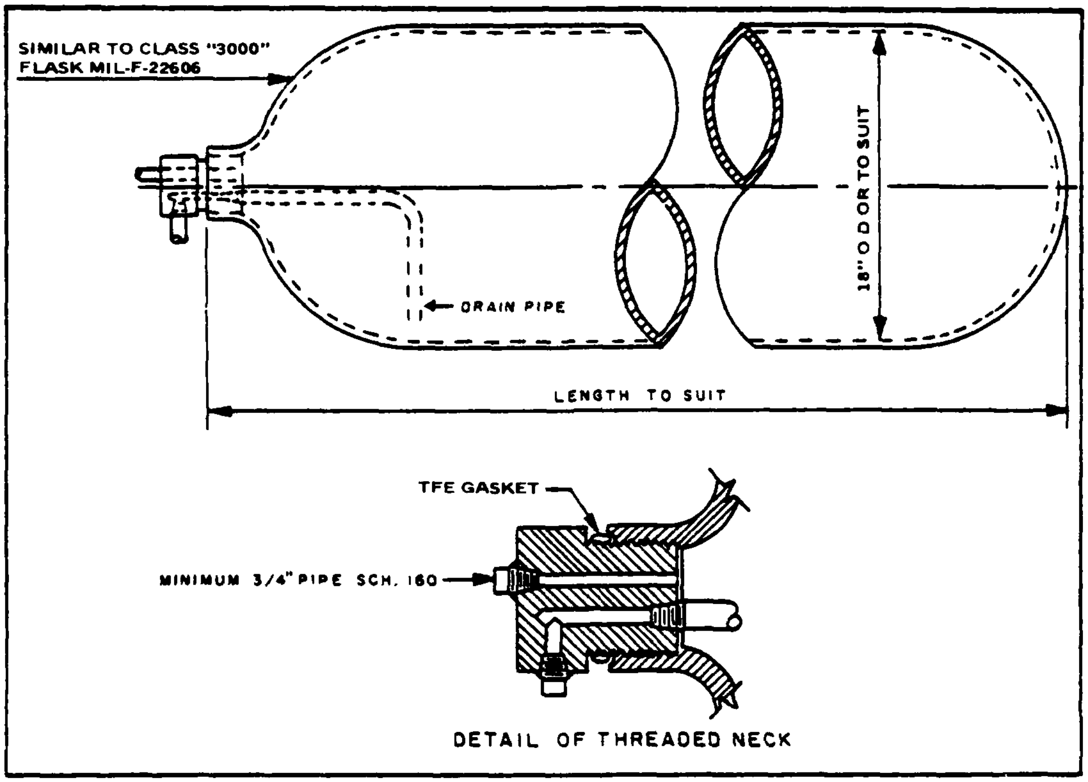

FIGURE 1
Helium Storage Cylinder for Pressure up to 3,000 psig

d. Truck Trailers. Provide truck trailers for those service points, some distance from the high pressure storage tanks, that are not accessible to the helium distribution piping system. Where the delivery point of railroad tank cars is some distance away from the use point, truck trailers can make the transfer with the aid of a compressor station. The trailers hold several cylinders that must meet ICC-3A and ICC-3AA specifications, and have capacities of 29,000 to 50,000 cubic feet of helium (at 70°F and 14.7 psia) at 2,400 to 3,000 psig.

e. Portable Storage. Use cylinders having about 1.5 cubic feet volume, holding 185 cubic feet of helium (at 70°F and 14.7 psia) at 1800 psig, or more at higher pressures. The cylinders are built in accordance with ICC-3A and ICC-3AA specifications.

3. REPURIFICATION PLANT. Where economically justified and where the purity of helium has been reduced by diffusion with air in a process, the purity shall be restored by a repurification system so that the helium can be reused and the tank cars need only make up the loss of helium through leakage and purging. The following methods of purifying helium have been used in the past:

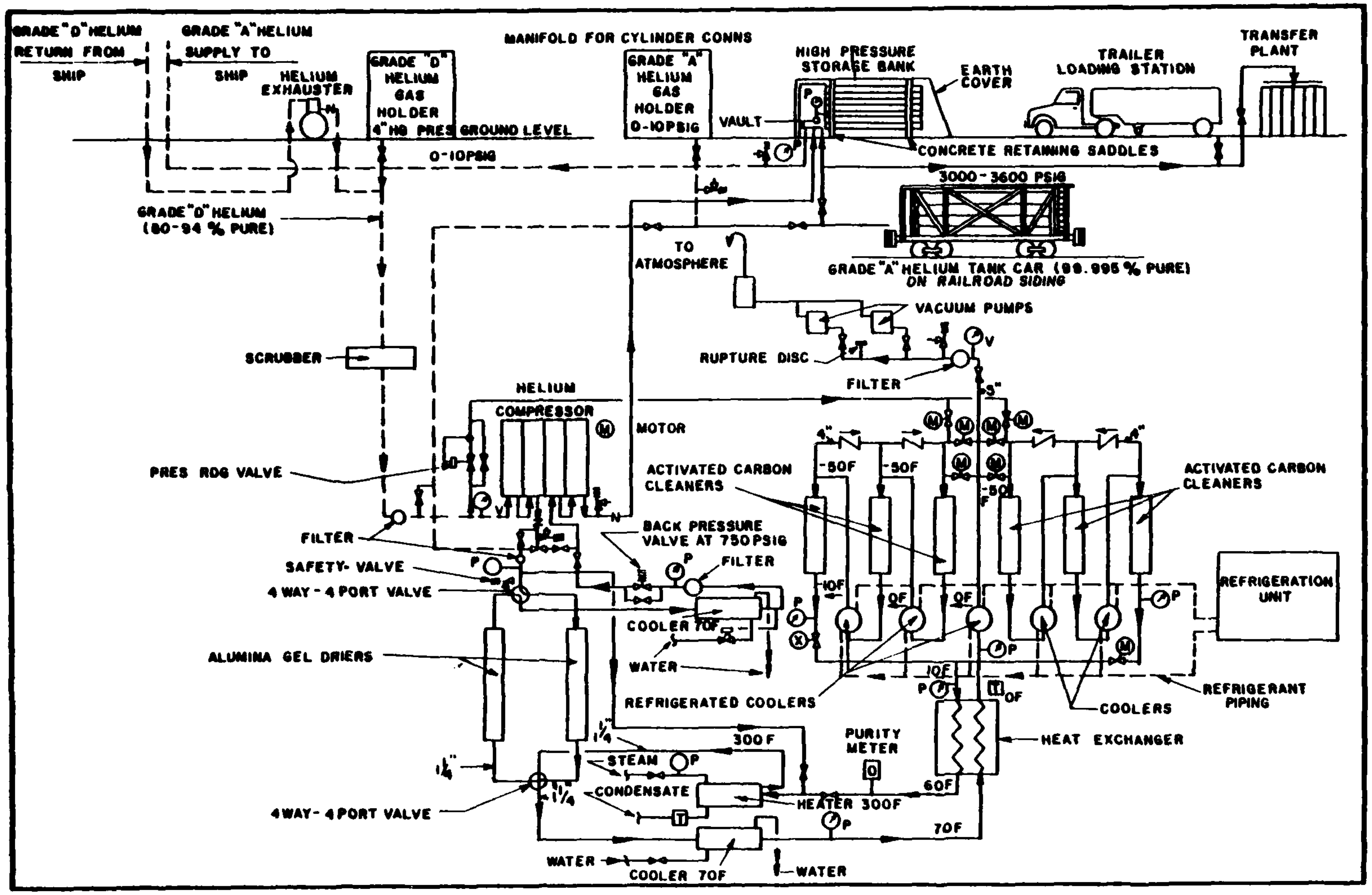

FIGURE 2
Helium Handling, Storage, and Purification at a Lighter-Than-Air Station

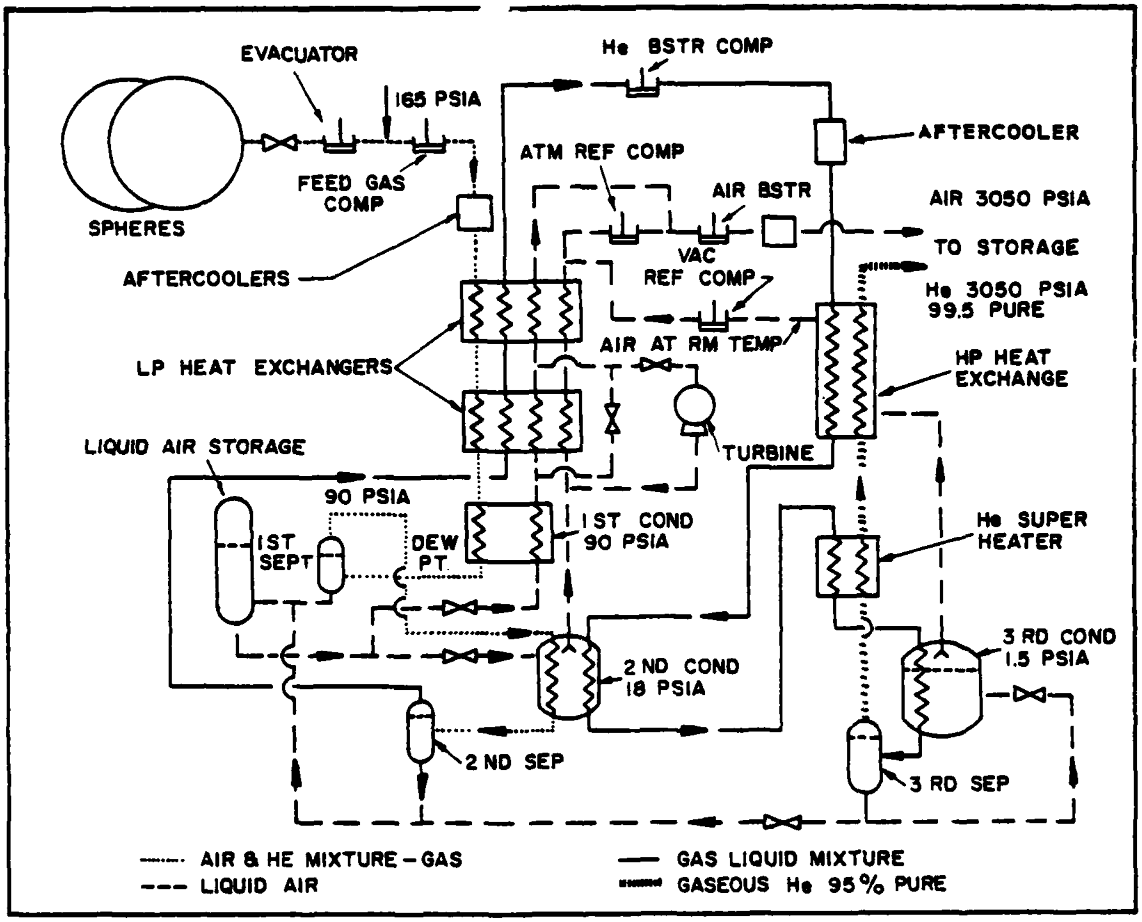

FIGURE 3
Helium Air Separation System for a Supersonic Wind Tunnel

a. Dehydrating and Cleaning Helium.

(1) Procedure. This method was used in some lighter-than-air stations, notably Lakehurst, N.J., and Weeksville, N.C. A schematic diagram of such a purification plant is shown in Figure 2. The total purification rate is 18,000 cubic feet per hour of free helium.

(a) After two compression stages, the contaminated gas, at over 750 psig, is dried in an aluminum gel tower, cooled to room temperature, and passed through a heat exchanger, where it loses more heat to the cleaned countercurrent helium gas.

(b) The crude gas then passes alternately through two banks of several refrigerated coolers and activated carbon cleaners in series. The nitrogen and oxygen, having been chilled close to their dewpoints in refrigerated coolers, are retained by the activated carbon, allowing the cleaned helium to pass through the cleaners.

(c) In order to reactivate one tank of carbon cleaners, the flow of helium is changed to the other tank and the tank to be reactivated is connected to the evacuating pump which is discharged into the atmosphere.

(d) After passing through the cleaners, the helium is heated to room temperature by the crude helium in the heat exchanger and then to 300°F by a steam heater. The warm helium is subsequently passed through a second aluminum gel drier to reactivate the drier, after which it is cooled to room temperature, returned to the third and fourth stages of the compressor, and discharged into the high pressure storage cylinders.

(e) This method cleans an 80 percent pure crude helium gas to 99.5 percent purity. The vacuum pumps are also used to evacuate and purge helium distribution lines.

(2) Compressor Characteristics. The compressor shall be capable of delivering the plant capacity of free helium (measured at 70°F and 14.7 psia) against the highest storage pressure.

(a) Compressors shall be capable of controlling the gas volume between one-third and full capacity and still maintain temperature and pressure conditions that will not injure the compressors.

(b) Compressors are usually of the four-stage type, of crosshead and piston rod construction, equipped with suitable intercoolers and aftercoolers and with hand unloaders.

(c) Compressors shall be equipped with a suitable relief valve on each stage.

(d) An automatic temperature control device shall be included on compressors, to stop the motor in case of failure of circulating waterflow.

(e) Compressors shall be driven by a synchronous motor, either direct connected or by V-belt drive, with direct connected exciter.

(3) Circulating Water. An adequate amount of cooling water is required for cylinder jackets, cylinder heads, intercoolers, aftercoolers, and heat exchangers for proper operation.

(a) Sea water can be used directly for cooling if the compressor design is suitable and the outlet water temperature does not exceed 130°F, but an intermediate tube and shell heat exchanger is recommended.

(b) When only city or potable water is available and its use is restricted, cooling towers should be used for cooling and circulating water.

(4) Trace Impurities in Helium. The Department of Interior, Bureau of Mines, has developed an impurity test apparatus, in which a concentrated impurity sample is analyzed on a mass spectrometer.

b. Condensing Gaseous Impurities.

(1) Compressors. For the supersonic wind tunnel at Ames Research Center, shown in Figure 3, the mixture of helium and air in the vacuum spheres, resulting from each blowdown cycle, must be separated into pure helium and pure air, and returned to separate high pressure storage vessels before repeating the cycle (duration about 30 minutes).

(a) Two tandem driven reciprocating evacuator compressor units are used, each unit capable of independent operation and of handling one-half the total pumping capacity.

(b) The helium-air mixture is evacuated from the vacuum spheres in the first stage of the compressor, and compressed in three further stages to 165 psia, after which the air is separated and the helium purified, and then compressed separately in the remaining four stages of the compressor to the final pressure.

(c) The compressor capacity rate is 350 pounds per minute per unit for two-thirds of the cycle.

(2) Air Separation. Separation of air from helium is effected by air condensation in three stages.

(a) About 75 percent of the air is condensed in the first condenser and separated in the first separator at 90 psia. Most of the remaining air in the gaseous mixture from the first separator will condense in the second condenser (at 18 psia) and separate in the second separator.

(b) The liquid (condensed) air from the first and second separators is transferred to the liquid air storage, from which it passes in parallel through the first and second condensers, where the air will boil to condense the mixture of incoming air and helium. Both liquid air streams are then warmed to room temperature in low pressure heat exchangers, and compressed to storage at 3050 psia.

(c) Some of the 90 psia air is bypassed after the first low pressure heat exchanger (90 psia), and is expanded through a turbine to the pressure (18 psia) and temperature of the air from the second condenser in order to supply the necessary refrigeration. A portion of the 90 psia air is bypassed around the first low pressure heat exchanger (turbine inlet) to regulate the turbine discharge temperature.

(3) Final Purification. The crude helium gas from the second separator is heated to room temperature in passing through the low pressure heat exchangers, pressurized to over 3,050 psia in the helium compressor, and is cooled nearly to its dewpoint in the high pressure heat exchanger.

(a) Part of the air remaining in the crude helium is condensed in the second condenser, more in the helium superheater, and the final amount in the third condenser. The separation as liquid air takes place in the third separator.

(b) The pure helium (99.5 percent pure), separated in the third separator, is heated in the superheater and the high pressure heat exchangers to the room temperature, and discharged to storage.

c. Parallel Helium and Gas Cycles. A third method, antedating the other two, has been used in Lakehurst, N.J., and Sunnyvale, Calif. Repurification is effected by passing the contaminated helium gas at high pressure, but low temperature, through coils surrounded by liquid air. The impurities liquefy and are drawn off, while the helium, possessing a lower point of liquefaction, remains in its gaseous state and passes to the storage cylinders. The Sunnyvale purification plant consists of two units designed to operate separately or together, and each is designed to process 30,000 cubic feet per hour (at 70°F and 14.7 psia) of impure helium containing 80 percent helium and 20 percent air. All of the various elements of the helium separation cycle are designed for a working pressure of 2,500 psig. The purity of the helium after passing through the plant is greater than 98.5 percent.

4. DISTRIBUTION SYSTEMS. Provide a flow diagram and piping as follows:

a. Flow Diagram. Provide a flow and piping diagram for the process, showing supply piping to the equipment and return piping for purging the equipment and the supply piping, so that the evacuated helium gas can be reclaimed. See Figures 2 and 3 for typical schematic diagrams.

b. Distribution Piping. Distribution piping shall not be of greater length than required for the service.

(1) Connections. Mechanical flexibility shall be provided by bends, loops, and changes in direction. Each storage cylinder should be connected to a manifold through a stop valve (not to be used for throttling). The manifold should be connected through a master globe valve to the distribution header. One pressure gage and one relief valve for the tank shall be installed on the manifold ahead of the master valve.

(2) Pressure. Piping shall be arranged so that tank cars or trailers can equalize pressure in the storage tank before using the compressors. Install a pressure relief valve backed up by a large rupture disc in all vacuum leads.

c. Piping Design. Piping of helium and compressed air only shall be designed in accordance with ANSI B31, Code for Pressure Piping (see References). If the substitution of hydrogen or other flammable gas for helium is contemplated, the helium piping shall be designed according to ANSI B31.8 (see References). Piping for steam, air, and water shall conform to the requirements of ANSI B31.1.

(1) Pipe. Piping for helium and compressed air only shall be seamless carbon steel pipe conforming to ASTM A106 (see References). Allowable working pressures are listed in Table 1.

(a) Welding. All welding shall be done in accordance with ANSI B31, Code for Pressure Piping (see References), using either butt or socket welding fittings, depending on size. Radiograph all welds under paved areas. Radiograph a minimum of one welded joint out of ten in other locations. Examine remaining pipe welds by visual examination method.

(b) Arrangement. Use a minimum size of 1 inch (except at instrument connections), which gives good mechanical strength to piping and valves, and allows wider support spacing than smaller sizes. Piping shall be shop fabricated in assemblies, cleaned by pickling, and given a passivation treatment to produce a thin iron phosphate coating inside, thus ensuring the purity of the helium. Vent piping shall be galvanized to avoid rusting on the inside.

(2) Hose. Avoid using a piping system made of rubber and other types of flexible hose, that are highly permeable to helium.

(3) Valves. Use a globe valve at the end of the common manifold for throttling, not at the helium cylinder valves. The plug and seat of any valve shall be of different materials. Lubricated plug valves shall not be used,

TABLE 1
Allowable Working Pressures In Helium and Compressed
Air Piping from Code for Pressure Piping
(ANSI B31) for ASTM A106, Seamless Steel Pipe

Nominal pipe size (in.)	Schedule	Wall thickness (in.)	Allowable working pressures			
			Grade A		Grade B	
			100° F	450° F	100° F	450° F
1/2......	40	.109	2040	1770	2380	2060
3/4......	40	.113	1750	1510	2040	1760
	80	.154	3110	2700	3630	3150
1............	40	.133	1900	1650	2210	1920
	80	.179	3130	2710	3650	3160
	160	.250	5150	4470	6010	5210
1-1/4......	40	.140	1530	1420	1910	1650
	80	.191	2700	2340	3150	2730
	160	.250	3990	3460	4650	4030
1-1/2......	40	.145	1510	1310	1760	1530
	80	.200	2510	2170	2920	2530
	160	.281	4050	3510	4720	4090
2............	40	.154	1330	1150	1550	1340
	80	.218	2240	1950	2620	2270
	160	.343	4140	3590	4830	4190
2-1/2......	40	.203	1660	1440	1940	1680
	80	.276	2540	2200	2960	2570
	160	.375	3780	3280	4410	3820
3............	40	.216	1480	1280	1730	1500
	80	.300	2300	2000	2680	2330
	160	.438	3710	3220	4330	3760
4............	40	.237	1300	1130	1520	1320
	80	.337	2050	1780	2390	2070
	160	.531	3590	3110	4180	3620
5............	40	.258	1170	1020	1370	1180
	80	.375	1880	1630	2190	1900
	160	.625	3470	3010	4050	3510
6............	40	.280	1090	950	1270	1100
	80	.432	1860	1610	2170	1880
	160	.718	3380	2930	3950	3420
8............	40	.322	990	860	1160	1000
	80	.500	1680	1460	1960	1700
	160	.906	3330	2890	3890	3370
10............	40	.365	920	800	1080	940
	60	.500	1340	1160	1568	1360
	160	1.125	3370	2920	3930	3400
12............	Standard	.375	800	700	940	810
	extra-strong.	.500	1130	980	1310	1140
	160	1.312	3330	2890	3890	3370

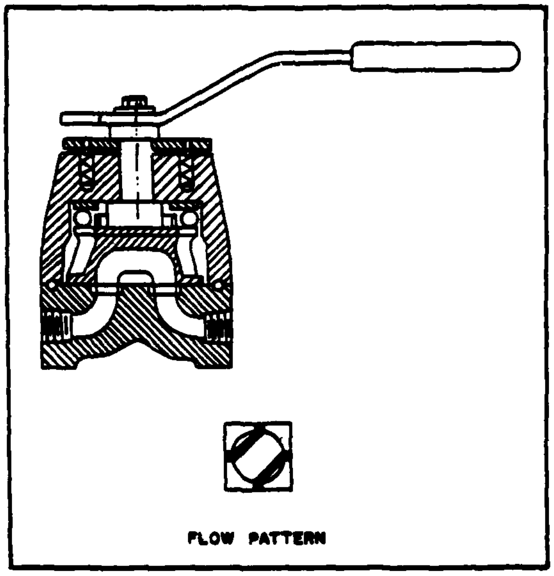

FIGURE 4
Four-Way Four-Port Valve

because of the danger of the lubricants entering the system. Four-port valves shall be of the shear type, as illustrated in Figure 4.

(4) Pressure Reducing Station. The pressure reducing valve shall be a single-seated, tight-closing, air-loaded diaphragm type. The pressure reducing station shall comprise (in succession): (a) bypass connection with shutoff valve, (b) shutoff valve, (c) strainer with blowdown, (d) pressure reducing valve, (e) bypass connection, (f) relief valve, and (g) pressure gage. Automatic pressure regulators for supplying high pressure stored gas to lighter-than-air ships have not been satisfactory.

(5) Relief Valves. These valves shall be installed as required, to protect vessels and piping from pressures above their approved rating.

(6) Strainers and Oil Mist Extractors. Fine mesh screen strainers shall be installed in suction piping to compressors. Oil mist extractors shall be installed in discharge piping from diaphragm compressors, to remove oil in case of diaphragm rupture.

d. Pipe Sizing. Piping should be sized to ensure fluid velocities under 100 feet per second. The rational formulas (equations 1, 2, 3, and 4) and Figure 5 should be used to determine the pressure drop in helium and compressed air pipes.

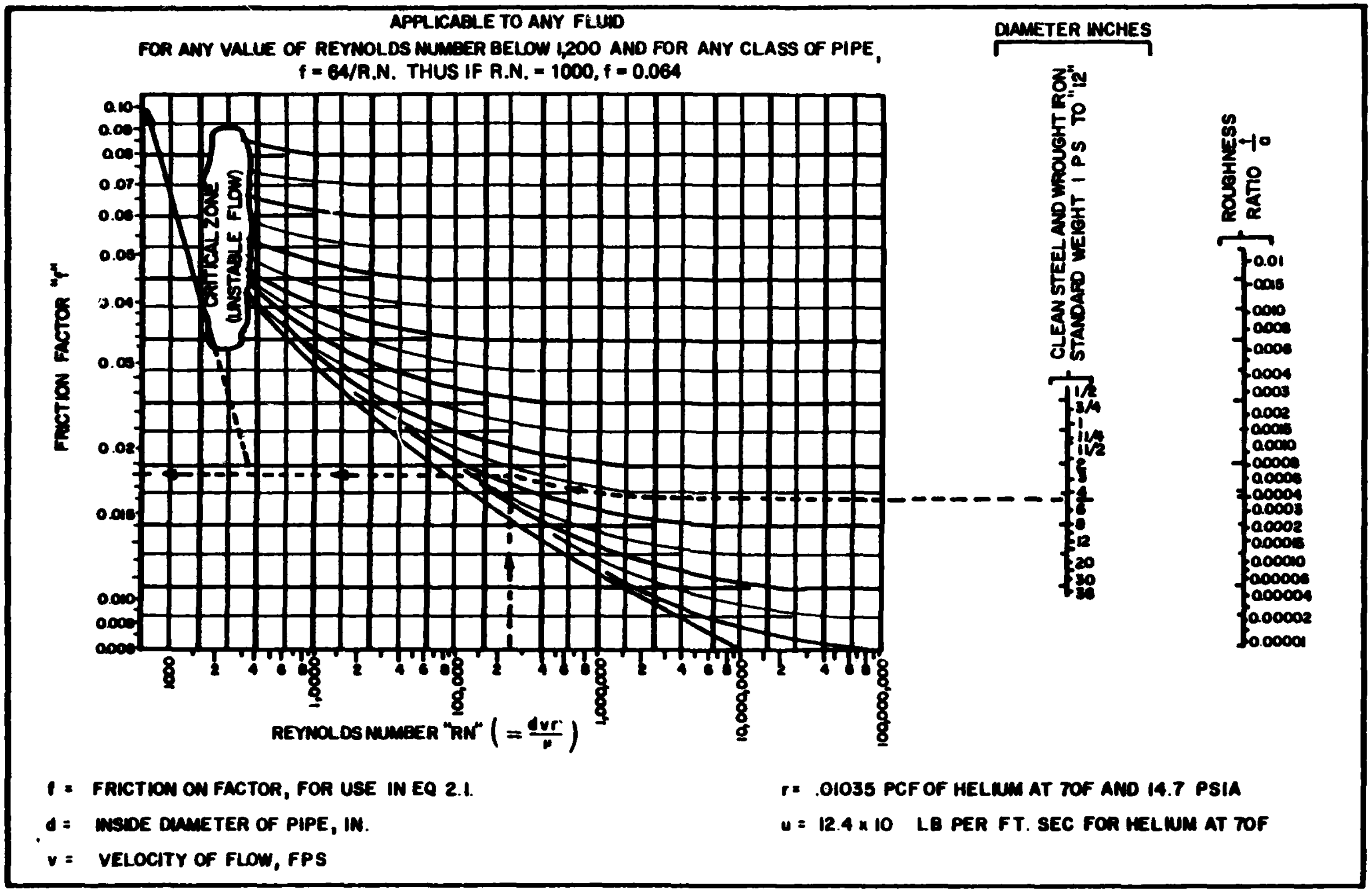

FIGURE 5
Friction Factor for Rational Flow Formula

$$p = \frac{0.0013 \times f \times L \times r \times v_2}{d} \quad (1)$$

p = pressure drop (psi).
f = friction factor from Figure 5.
L = equivalent length of piping (ft).

$$r = .01035 \times \frac{P_2}{14.7} \times \frac{530}{T_2} = .374 \times \frac{P_2}{T_2} \text{ (pcf for (helium)} \quad (2)$$

$$r = .075 \times \frac{P_2}{14.7} \times \frac{530}{T_2} = 2.71 \times \frac{P_2}{T_2} \text{ (pcf for air)} \quad (3)$$

where: P_2 = absolute average pressure of helium or air in pipe (psia).
T_2 = absolute temperature of helium, or air in pipe (F).

$$v = \frac{0.00408 \times Q_h}{P_2 \times A} \quad (4)$$

where: v = fluid velocity of helium or compressed air (fps).
Q_h = volume (cu ft per hr) of helium or compressed air at $70^{o}F$ and 14.7 (psia).
A = cross section area of pipe (sq ft).
d = inside diameter of pipe (in.).

e. Underground Pipelines. Underground pipelines shall be buried below the frostline. These lines shall be coated with polyvinyl chloride.

(1) In Corrosive Soils. Well slacked lime, loam, or clay shall be placed around pipes in corrosive soils.

(2) Under Railroad Tracks. Lines crossing under railroad tracks shall be placed in culverts sufficiently deep to avoid mechanical injury.

f. Testing. Prior to installation, all piping shall be tested by competent personnel, including an engineer responsible for safety being present during testing. All piping shall be subject to a hydrostatic test of 150 percent of design working pressure in accordance with ASME Boiler Code for Unfired Pressure Vessels, and ANSI B31.1, Section 2. After satisfactory completion of the hydrostatic test and cleaning, the piping shall be charged with clean air to a pressure equal to the design working pressure of the system.

5. TRANSFER SHOP. Provide a shop for receiving empty 1.5 cubic foot cylinders, and for shipping them out in trucks or railroad cars after they have been washed, tested, stamped, or painted in accordance with ICC-3A and ICC-3AA regulations.

a. Retesting Cylinders. Cylinders with expired ratings shall be tested hydrostatically to a pressure equal to five-thirds that of the service pressure; for this, a hydrostatic test stand and pump must be provided. A wash rack should be furnished for cleaning cylinders in an inverted position. A small portable fan-driven electric air heater, with an extension pipe reaching the bottom of the cylinder, is necessary for drying the cylinders.

b. Filling. At least two multicylinder duplex unit manifolds with pressure regulators shall be used for filling the cylinders. Run a 1-inch high pressure helium line overhead from the main supply line to the truck fill connection at the trailer loading platform, with drop lines to the cylinder filling manifolds.

c. Transfer Shed. An industrial shed shall be provided adjacent to the railroad spur and the delivery road, with its floor at truck loading height. The walls shall be of sufficient strength to provide protection against a cylinder rupture, and shall be unbroken except for windows and doors for access (from the outside only).

Section 3. RELATED FACILITIES

1. ARCHITECTURAL REQUIREMENTS. Related facilities purification plant and high pressure storage vault architectural requirements are as follows:

a. Purification Plant. Provide an industrial shop building to enclose the purification plant equipment, and the piping alongside the railroad spur on which the tank cars will be unloaded.

(1) Housing. The building should have sufficient floor space and height to house the equipment called for in the flow diagram, plus sufficient aisle space for making operating changes and for inspecting, cleaning, and dismantling of the equipment. Also provide the necessary platforms and ladders for access to elevated control valves and cleanout doors.

(2) Facilities. Adjacent to the building, provide a shed for a work shop, locker and toilet room, and office. A loading platform should be located outside the delivery door.

b. High Pressure Storage Vault. This enclosure shall house the manifold ends of the cylinders, together with the manifold pipe and the distribution header. One wall is the concrete cradle for the cylinders, while the other walls shall be strong enough to withstand a cylinder-end rupture and shall be unpierced, except for the access doors at either end.

2. STRUCTURAL REQUIREMENTS. Compressor foundations and hoists requirements are as follows:

a. Compressor Foundations. Foundation shall be of sufficient size and mass to ensure satisfactory performance. Follow the drawings and recommendations of manufacturers for their equipment. Insulate large compressors from the building structure to dampen vibration and sound.

b. Hoists. To facilitate service, provide hoists of suitable size over the large compressors and towers in the purification plant.

3. MECHANICAL REQUIREMENTS. Provide plumbing, ventilation, and heating as follows:

a. Plumbing. Provide water supply and drains as required.

b. Ventilating and Heating. Helium gas is chemically inert and not toxic and, basically, the criteria for heating and ventilating given in the NAVFAC DM-3 Series are applicable.

4. ELECTRICAL REQUIREMENTS. Buildings shall be well lighted. Switchgear for electric motor-driven compressors shall be in the purification plant room. Electric service required by the synchronous motors shall be supplied.

METRIC CONVERSION FACTORS

To convert from	To	Multiply by
AREA		
ft^2	m^2	9.290E-02
in^2	cm^2	6.452E+00
kCM	mm^2	5.067E-01
LENGTH		
ft	km	3.048E-04
ft	m	3.048E-01
in	Cm	2.540E+00
in	mm	2.540E-01
mile (statute)	km	1.609E+00
LIGHT		
footcandles	dekalux	1.076E+00
MASS		
oz	g	2.835E+01
lb	kg	4.536E-01
ton (short)	kg	9.072E+02
MASS PER UNIT AREA		
lb/ft^2	kg/m^2	4.882E+00
lb/ft^2 (psi)	kg/m^2	7.031E+02
TEMPERATURE		
degree Fahrenheit	degree Celsius	$t^oC=(t^oF-32)/1.8$

NOTATION. Factors are written as a number greater than one and less than ten with three decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

5.067E-01 is 5.067×10^{-1} or 0.5067

Similarly:

2.835E+01 is 2.835×10^{1} or 28.35

REFERENCES

(Publications containing criteria cited in this manual)

Unfired Pressure Vessel Code, American Society of Mechanical Engineers, (ASME), New York, N.Y.

Code for Pressure Piping, ANSI B-31, American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

Seamless Carbon Steel Pipe for High Temperature Service, ASTM A-106, American Society for Testing and Materials, Philadelphia, PA 19103.

NAVFACENGCOM Documents available at U.S. Naval Publications and Forms Center, Philadelphia, PA 19120. TWX: 710-670-1685, TELEX: 834295, AUTOVON telephone number 422-3321. The stock number is necessary for ordering these documents and should be requested from the NAVFACENGCOM Division in your area.

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